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THE IMPACT OF INSTITUTIONS ON INNOVATION NETWORKS: EMPIRICAL EVIDENCE FROM POLAND

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Abstract. Innovation networks may accelerate and improve the innovation process, while institutional pathologies may hamper it. This study employs the Kruskal-Wallis H test and regression analysis to determine if the relationship between institutions and innovation networks does exist among the investigated variables. The purpose of the study was to find out whether cooperation with special local institutions influences the innovative behaviour of local governments manifested by participation in innovation networks or innovation networks based on formal institutions limit institutional pathologies better than informal ones. Current paper presents results of an empirical study conducted through survey among all local governments in Poland. The findings show that previous cooperation with special local institutions influences the innovation behaviour of local governments or innovation networks based on formal rules limit the institutional pathologies of innovation networks better than those based on sanctions, common values, codes of ethics, governance codes or culture. The investigated problem is significant, as properly functioning innovation networks may generate incremental innovations, which may help to solve the contemporary challenges. The practical implications for national regulatory bodies highlight the need for an enforcement mechanism which may support the formalisation of innovation networks.

Keywords: innovation networks, innovations, institutions, institutional analysis, parametric and non-parametric statistics, empirical research, Poland, the Kruskal-Wallis H test, regression analysis.

JEL Classification: O31, O30, D02.

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Introduction

Nowadays, innovations are of critical importance, not only to national economies (Kraftova & Kraft, 2018; Sell, 2020) but also in overcoming contemporary challenges related to the fight with COVID-19 (Khan et al., 2021). However, in order to occur, innovations require networks, social diversity, socio-institutional infrastructure, and strong formal and informal institutions (Rodríguez-Pose & Crescenzi, 2008). Innovation networks, following Batterink et al. (2010), may be understood as the relationships between at least three independent organisations connected by a set of long-term cooperation ties that seek innovation. Innovation networks are crucial to the innovation process because, due to the socio-cultural structures of such networks and the common institutional environment inside the network, their members may stimulate collective learning or continuous innovation (Asheim & Isaksen, 2002, p. 83; Levén et al., 2014). Moreover, innovation networks may minimise transaction costs or risk connected with the innovation process by adding more flexibility to it (Ekboir, 2012). Thanks to this, innovation networks may accelerate and improve the innovation process (Barsh et al., 2008). In addition, De Propris (2002) highlights the fact that innovation networks are much more important to innovation than investments in research and development, which usually are not customised to the situation in different countries and regions (Banelienė & Melnikas, 2020).

According to the theory of innovation networks, the concept of an entrepreneurial ecosystem, the new economics of innovation or the new institutional economy, innovation networks are embedded in institutional frameworks at the local, regional, national and international levels (Ahrweiler et al., 2014, p. 1; Malecki, 2018; Xu & Doobson, 2019). Moreover, the diffusion of innovation requires overcoming technical, economic, social or institutional obstacles (Taalbi, 2017), and institutional pathologies inside innovation networks may hamper the innovation process inside such networks. For this reason, innovation networks require strong formal and informal institutions (Godlewska, 2021). On the one hand, informal institutions such as trust, creativity, or collaboration may directly influence the success of innovation networks (Sandberg et al., 2015). On the other hand, formal institutions such as regulations or law also matter when it comes to enabling or disabling innovations and enhancing or reducing the incentive to innovate (Pelkmans & Renda, 2014; Godlewska, 2021) and to establish innovation networks.

According to the authors' best knowledge, common literature to date does not cover studies on the impact of institutions on the institutional pathologies of innovation networks or on the innovative behaviour of local governments. Previous research focused on innovation networks from different angles and primarily managerial perspectives such as:

i) Internal relations between members (Salavisa et al., 2012);
ii) Regional, global or translocal context (Chaminade & Plechero, 2015; Cano-Kollmann et al., 2018; Avelino et al., 2020);
iii) Internal organisation (Aalberts & Dolfsma, 2015);
iv) Orchestration (Hurmelinna-Laukkanen & Nätti, 2018);
v) Links between members (Masiello et al., 2015);
vi) Mechanisms of selection of members (Baum et al., 2010; Shazi et al., 2015);
vii) Internal and external knowledge exchanges and flows or leaks (Alberti & Pizzurno, 2015, 2017);

viii) Optimal distance between members (Fitjar et al., 2016);
ix) Network performance (Jun et al., 2020);
x) Network policy (Rubach et al., 2017);
xi) Ecosystems (Möller & Halinen, 2017).

Importantly, Hodgson (2019) underlines that the interaction between institutions and other factors such as technology or innovation networks needs to be better understood. For this reason, the purpose of this study was to determine:

i) If cooperation between local governments (hereafter LGs) and special local institutions may encourage LGs to participate in innovation networks;
ii) If a particular type of innovation network matters in terms of the interplay between formal and informal institutions;
iii) If formal settings (institutions) alone limit the institutional pathologies of innovation networks.

The paper's contribution is fourfold:

i) LGs who cooperate with special local institutions are much more eager to participate in innovation networks than LGs who do not cooperate with these institutions;
ii) LGs participate in formal innovation networks based on rules and relations;
iii) The type of innovation network does not matter when it comes to the interplay between formal and informal institutions; and
iv) Innovation networks based on formal rules of cooperation between members limit the institutional pathologies of innovation networks such as opportunism, distrust, lack of stability, rent-seeking behaviour or individual interest better than innovation networks based on sanctions, monitoring systems, common values and norms, code of ethics, governance codes or culture.

The authors deliberately chose Poland as an example of a country with an innovation development gap between regions (Czudec et al., 2019). The authors believe that the particular pattern of innovation network pathologies or innovative behaviour of LGs identified in Poland is relevant to other countries at the intermediate development stage in Europe, Africa, Asia and Latin America. Moreover, the practical implications for national regulatory bodies highlight the need for an enforcement mechanism employing which managers or orchestrators may support the formalisation of innovation networks.

1. Literature review

1.1. Special local institutions

LGs in Poland, according to the law (Polish Act of 8 March 1990 on Local Self-Government, or the European Charter of Local Self-Government, 1985), do not have to support the local innovation process directly. Despite this, some LGs do participate in innovation networks. The question is why some of them support the local innovation process through participation in innovation networks, while others do not. Is it the self-enforcement mechanism (Godlewska & Morawska, 2020), the supportive institutional environment (Wen et al., 2021), or is it due to prior cooperation with particular institutions?

Many post-communist countries are lagging in their technological development (Santos-Arteaga et al., 2020) and the assistance offered by their central governments in the innovation process at local or regional level is ineffective. For these reasons, the innovative behaviour of LGs, which may support the local innovation process by participating in innovation networks, is essential. In addition, Gebauer et al. (2005) highlight the fact that innovation networks are vital to innovation and technological change based on research into German cities. LGs co-exist in the local environment with different types of institutions. It is essential to discern whether previous cooperation with local institutions which are active in their territory may help and motivate them to undertake innovative behaviour.

Moreover, collaboration between actors of entrepreneurial ecosystem such as entrepreneurs and/or innovators, local government or special institutions is essential. LGs and special local institutions may increase the innovation output of innovation networks thanks to cooperation (Cap et al., 2019). Innovation networks are a major driver of innovation and one of the most important factors of the entrepreneurial ecosystem (Cap et al., 2019).

There is a heated debate on whether or not organisations such as technology and science parks or business chambers may be treated as special local institutions (SLIs) in the literature on the subject. On the one hand, North (1990) argued that institutions supporting innovation networks should be divided by the rule component into:

i) Formal institutions such as formal rules of cooperation between members of innovation networks; laws such as property rights law or innovation law and constitution and
ii) Informal institutions such as innovative and entrepreneurial culture, customs, norms and values, such as trust, reciprocity, creativity, cooperation or positive attitude to risk. On the other hand, Hodgson (2006) highlights those institutions are systems of rules, which are socially embedded, in a local context. It is why we may treat organisations as "a special kind of institution, with additional features" (Hodgson, 2006, p. 8).

Local institutions matter for entrepreneurship development (Acs et al., 2008) and innovation (Daniluk, 2019). The theoretical and empirical literature on SLIs highlight:

i) The critical role of local institutions in transnational regional innovation networks in China (Y.-C. Chen, 2007);
ii) Support for companies or LGs by SLIs such as business environment institutions which are key elements of an efficient innovation system (Daniluk, 2019);
iii) The significance of cooperation between LGs and SLIs such as science parks for supporting the innovation process at a regional level (Zeng et al., 2010).

The catalogue of SLIs consists of R&D institutes, technology transfer centres, technology and business incubators, technology and science parks, loan and guarantee funds, business chambers, local or regional development agencies, etc., which are active on the territory of LGs. These SLIs provide various forms of support for innovators and innovation networks, such as advice on prototype development or commercialisation of innovations or patent registration, etc. Therefore, in this paper, based on the results of research by Zeng et al. (2010), the following hypothesis was introduced:

H1. *Cooperation with special local institutions influences local governments' innovative behaviour, manifested by participation in innovation networks.*

1.2. Innovation networks based on formal and informal institutions

Innovations require strong institutions, democracy, economic and legal freedom (Phelps, 2013). In the literature on the subject, there is a heated debate on which institutions matter for innovation networks to be successful and free of institutional pathologies. Formal institutions such as formal rules of cooperation or innovation law (Pelkmans & Renda, 2014), similarly to informal institutions such as entrepreneurial and innovative culture (Shahzad et al., 2017), trust (Sztompka, 2007), creativity (Chen et al., 2008) or cooperation (Lundvall, 2007) matter when it comes to innovation networks.

Innovation networks may be based only on relations, rules, or rules and relations. However, Salavisa et al. (2012) distinguish only formal (based on rules) and informal (based on relationships) innovation networks. The theoretical and empirical literature on the subject underlines that

i) Relationship-based innovation networks, which focus on cooperation and trust between members, lead to openness, communication, foresight and discipline inside networks (Oughton et al., 2002);
ii) Rules-based innovation networks rely on formal agreements or contracts and include, for example, formal statements on the sharing of tasks, costs, benefits or revenues (Powell & Grodal, 2005);
iii) Each innovation network needs a certain amount of control and formal regulations are required to ensure the success of such networks (Ojasalo, 2008).

Most recently, scholars have identified those different types of innovation networks which may be based on different sets of institutions such as:

i) Strategic alliances or sector forums focused on the selection of partners based on their informal institutions such as social capital (Baum et al., 2010);
ii) Regional clusters or innovation networks relying on strong formal institutions such as ground rules of intellectual property management (Tidd, 2006);
iii) Public-private innovation networks (Jun et al., 2020) or clusters (Alberti & Pizzurno, 2015) relying on cooperation with different institutions, for example SLIs;
iv) Neighbourhood networks or inter-municipal collaborations, of which LGs are vital members, relying on the interplay between formal and informal institutions with sanctions or rewards (Aars & Fimreite, 2005).

Therefore, based on the results of research by Aars and Fimreite (2005), the following hypothesis was introduced:

H2. *Inter-municipal* (*intercity*) *innovation networks are based on the interplay between formal and informal institutions.*

1.3. Institutional pathologies of innovation networks

As with other organisations, innovation networks may be affected by conflicts, disputes, or a lack of coordination. Institutional pathologies of innovation networks may relate to:

i) A lack of sanctions for breaking formal rules (Godlewska & Morawska, 2020);
ii) A lack of trust (Skardon, 2011);

iii) A lack of empowerment (Avelino et al., 2020);
iv) Opportunistic or rent-seeking behaviour (Williamson, 1993);
v) Free-riding behaviour or moral hazard (Corsaro et al., 2012).

Theoretical and empirical literature on the subject underlines that:

i) Weak or inappropriate formal regulations may affect the willingness, capability or opportunity of entrepreneurs to innovate (Ashford, 2000) which may result in a lack of trust between innovation network members or rent-seeking behaviour;
ii) Informal institutions such as culture, norms or values may support formal institutions (Helmke & Levitsky, 2004) in order to overcome opportunistic behaviour by some members of innovation networks;
iii) Formal institutions may suppress, conflict, ignore or "cooperate" with informal ones (Pejovich, 1999) in order to hamper or facilitate the institutional pathologies inside innovation networks;
iv) Formal institutions are essential to the innovation process because only formal institutions may limit the disruptive impact of innovations (Chiu, 2017) and may possibly also limit institutional pathologies in innovation networks.
v) Formal institutions are more efficient than sanctions or monitoring systems, thanks to people who obey the rules because they believe it is the right thing to do, not fear punishment (Hodgson, 2019).

Therefore, in this paper, based on the most recent studies by Chiu (2017) and Hodgson (2019), the following hypothesis was introduced:

H3. *Innovation networks based on formal rules limit institutional pathologies.*

2. Research methods

The theory of innovation networks highlights the critical importance of institutions (Y.-C. Chen, 2007). Aars and Fimreite (2005) underline the importance of the interplay between formal and informal institutions in innovation networks. In this paper, authors draw upon theories of innovation networks, institutions, entrepreneurial ecosystem concept and develop a conceptual model of the relationship between formal and informal institutions, and innovation networks (see Supplement 1). Moreover, Gorzelany-Dziadkowiec et al. (2019) highlight the critical importance of LGs to studying the innovation process at the local level. For this reason, in response to calls for research on the interaction between institutions and innovation networks (Hodgson, 2019) and to better understand the state of play or investigate research gaps, the authors chose a six-stage approach (see Supplement 2).

Despite the widely held belief that institutions matter when it comes to innovation networks, there were no studies that provided evidence of whether:

i) Cooperation with SLIs influences the innovative behaviour of LGs;
ii) LGs participate in formal or informal innovation networks based on rules, relations, or rules and relations;
iii) Types of innovation networks matter when it comes to the interplay between institutions;

iv) Formal institutions may limit the institutional pathologies of innovation networks. As such, these were the main objectives of this study.

Surprisingly, in Poland, there is no available list of active innovation networks. According to Aars and Fimreite (2005) research, LGs are members of innovation networks in Norway or small German cities, according to Gebauer et al. (2005). It is why the authors chose polish LGs. The article assumes that the responses of LGs, which are members of innovation networks, are similar to other potential members such as companies, universities or governmental agencies. The results of a study by Rehm et al. (2016) show that small and medium-sized enterprises also underline the importance of institutions such as research institutions to the success of innovation networks.

Although the innovation process is a multilevel phenomenon (Abbasi et al., 2019) and multilevel analysis is needed to analyse the occurrence of innovation, innovation networks are usually analysed through the lens of particular industry sectors (Bauer et al., 2018), particular players (members) (Desmarchelier et al., 2020), or processes such as knowledge transfer or connectedness (Aalbers et al., 2013). Moreover, Høegh-Guldberg et al. (2018) underline the fact that although innovation research stresses the complexity of the innovation process, network research which focuses on innovation networks is mainly based on linear regression analysis. However, in future, scholars should focus on multilevel analysis of innovation networks.

The analytical framework of the paper is based on Van Hecke's (2012) non-parametric methodology of the Kruskal-Wallis H test. Similarly, Min et al. (2020) also underline the advantages of non-parametric test methodology. The scope of analysis is based on research by Gorzelany-Dziadkowiec et al. (2019). Moreover, Ghazinoory et al. (2014) highlight that the method and chosen variables are influenced by the researchers' approach to the definition of the concept of the innovation network.

In order to achieve the objectives of the paper, empirical research on Polish LGs was conducted, and data were statistically processed and interpreted. The research was carried out from April 6, 2020, to April 30, 2020. An electronic survey questionnaire was prepared based on the literature review and checked during the pilot study. Data were acquired using an electronic survey in Polish containing quantitative and qualitative research questions, which was sent to $n = 2477$ local government units (LG, i.e. all rural, rural-urban and urban municipalities and cities with district rights, LAU level 2, formerly the NUTS level 5). The data collected covered the characteristics of LGs, such as the type of LGs, voivodeship, cooperation with SLIs, and participation in innovation networks. For these LGs who participated in innovation networks, the data collected also covered types of innovation networks, the role of LGs in innovation networks, the number of network members, characteristics of other members and leaders, network coordination mechanisms, the advantages/disadvantages of participation in innovation networks, types of innovation, network characteristics (formal and informal institutions or institutional pathologies) and values, networks activities, and cooperation with research and development institutions (the survey which was sent to LGs is in Supplement 3).

The authors employed the professional research platform Webankietka.pl to circulate the electronic survey among all LGs. The responsiveness rate from Polish LGs was $n = 208$

answers (records), i.e. 8.2% of the LG population. However, there were cases of duplicate and incomplete records. Instead of carrying out an imputation procedure, all incomplete or duplicate records were removed from the research sample. Finally, we obtained n = 184 complete records, i.e. 7.2% of LGs population (requiring n = min. 182). The sample had a 5% materiality level and a 7% maximum error (2SE). The research sample (n = 184) was not fully representative of all LGs because rural municipalities (57% of the sample vs 60% of the general population) and urban-rural municipalities (22% of the sample vs 25% of the general population) were under-represented, in contrast to urban municipalities (15% of the sample vs 12% of the general population) and cities with district rights (6% of the sample vs 3% of the general population) which were over-represented. This lack of full representativeness does not allow for a complete generalisation of research results for the entire population of LGs.

Our dependent variables (see Supplement 4) were:

i) Innovative behaviour of LGs. The variable (*meminne*) takes a value of 0 if LGs do not participate in innovation networks and 1 otherwise;
ii) Interplay between formal and informal institutions. The variable (*interpl*) takes a value of 0 if innovation networks are not based on the interplay between formal and informal institutions and 1 otherwise;
iii) Institutional pathologies of innovation networks. The variables (*complia*, *indimem*, *stabili* and *oppodis*) take a value of 0 if innovation networks are not affected by institutional pathologies and 1 otherwise.

The independent variables were chosen from the above mentioned electronic survey of Polish LGs. The list of independent variables was as follows (see Supplement 4):

i) Cooperation with SLIs (*coopsli*);
ii) Types of innovation networks (*typesin*);
iii) Formal and informal institutions (*formaru*, *codethi*, *sanncio*, *company*, *monisys*, *goverco* and *comcult*).

The Kolmogorov-Smirnov and Shapiro-Wilk tests' assumption of normal distribution was rejected for all hypotheses. The statistical analyses were conducted using IBM SPSS Statistics 26. The Kruskal-Wallis non-parametric test was employed. If the significance level was more significant than or equal to $\alpha = 0.05$, there was no reason to reject H0. However, when the value of α was less than 0.05, the null hypothesis was rejected. If the statistical value of χ^2 exceeds the value read from the chi-square distribution tables for $\alpha = 0.05$ and $v = k - 1$, it can be concluded that the test results confirm the significance of differences between the effects of the independent variable (controlled factor) on the dependent variable.

3. Results and discussion

3.1. Importance of special local institutions to the local innovation process

Gebauer et al. (2005), based on a study of small German cities, stress the importance of LGs to a successful innovation process at the local level, in line with our results. However, in Poland, only 26.63% of LGs (see Table 1) who participated in the study (49 out of 184) were members of innovation networks.

Table 1. Descriptive statistics – H1 (source: authors' compilation)

	N	Min	Max	Mean	Std. Deviation	Skewness		Kurtosis	
						Stat.	Std. Error	Stat.	Std. Error
coopsli	184	0	1	0.212	0.40981	1.421	0.179	0.020	0.356
meminne	184	0	1	0.266	0.44323	1.066	0.179	–0.873	0.356

Table 2. Spearman's *rho* correlation – H1 (source: authors' compilation)

Spearman's *rho*	coopsli	
meminne	Correlation Coefficient	0.470**
	Sig. (2-tailed)	0.000
	N	184

Note: **Correlation is significant at the 0.01 level (2-tailed).

The relationship between LGs cooperation with SLIs and LGs participation in innovation networks was statistically significant at the 0.01 level (2-tailed) (see Table 2).

Zeng et al. (2010) argue, in line with our results, that cooperation between LGs and science parks may support the innovation process at a regional level. For this reason, in order to find out if cooperation between LGs and SLIs at a local level (including but not limited to science parks) matter in terms of LG participation in innovation networks, the authors selected the test of difference significance, which allowed them to verify the null hypothesis:

H0. $INA = INB$ (there is equality of distribution functions of cooperation between LGs and SLIs in the compared population) against the alternative hypothesis:

H1. $INA \neq INB$ (there is no equality of distribution functions of cooperation between LGs and SLIs in the compared population),

where *INA* – dependent variable in the population of LGs who participate in innovation networks; *INB* – dependent variable in the population of LGs who do not participate in innovation networks.

Because of this, the first hypothesis was fully validated (see Table 3). The null hypothesis must be rejected because there is no equality of distribution functions in the compared population. It means that LGs who cooperate with SLIs are much more eager to participate as members in innovation networks than LGs who do not cooperate with SLIs.

Table 3. Kruskal Wallis test – H1 (source: authors' compilation)

Test Statistics	
	Meminne
Kruskal-Wallis H	40.379
df	1
Asymp. Sig.	0.000
Grouping Variable: *coopsli*	

In contrast to our results, Bai and Li (2011) argue that Chinese LGs harm the efficiency of regional innovation processes in China. However, our results confirm that SLIs support the participation of LGs in innovation networks, which may spur local innovation processes later on.

In line with our results, which stress the importance of SLIs, based on research into Polish and Belarusian companies, Daniluk (2019) highlights that SLIs such as business environment institutions are critical elements of an efficient innovation system. Similarly, based on a study of Spanish industrial districts, Molina-Morales (2002) emphasises the role of SLIs such as research centres, industrial policy agencies, academic institutions, or trade and professional associations in innovation processes at the local level, which is in line with our results. Moreover, Rycroft (2007) underlines the fact that innovations are linked to the type of innovation network members, the amount of collaboration between members of innovation networks and other institutions such as SLIs or potential institutional pathologies. Also, Y.-C. Chen (2007) highlights the critical role played by local institutions in Chinese innovation networks. Our results confirm that LGs that cooperate with SLIs are members of innovation networks, whereas LGs that do not cooperate with SLIs are usually not involved in innovation networks.

3.2. Inter-municipal innovation networks based on rules and relations

Shah and Shah (2006) argue that LGs should deal with market or government failures and engage in different local networks such as innovation networks. LG involvement in innovation networks may take various forms. Polish LGs (see Table 4) participated in formal innovation networks, most of which were based on:

i) Formal rules (*formaru*);
ii) Common values and norms (*comvano*);
iii) Common culture (*consult*).

However, innovation networks based on sanctions (*sanncio*), monitoring systems (*monisys*), codes of ethics (*codethi*), governance codes (*governor*) or interplay between formal rules and common values and norms (*interpl*) were scarce.

Table 4. Descriptive statistics – H2 (source: authors' compilation)

	N	Min	Max	Mean	Std. Deviation	Skewness		Kurtosis	
						Stat.	Std. Error	Stat.	Std. Error
typesin	49	1.00	10.0	4.5510	2.00064	0.020	0.340	0.718	0.668
formaru	49	0.00	1.00	0.3878	0.49229	0.475	0.340	–1.851	0.668
codethi	49	0.00	1.00	0.0408	0.19991	4.789	0.340	21.827	0.668
sanncio	49	0.00	1.00	0.0816	0.27664	3.153	0.340	8.280	0.668
comvano	49	0.00	1.00	0.2245	0.42157	1.363	0.340	–0.151	0.668
monisys	49	0.00	1.00	0.0408	0.19991	4.789	0.340	21.827	0.668
governor	49	0.00	1.00	0.0204	0.14286	7.000	0.340	49.000	0.668
comcult	49	0.00	1.00	0.1837	0.39123	1.686	0.340	0.876	0.668
interpl	49	0.00	1.00	0.1633	0.37344	1.880	0.340	1.599	0.668

These relations were statistically significant correlated between the type of innovation network and formal rules or common values and norms at the 0.05 level (2-tailed). For sanctions, monitoring systems, common culture, codes of ethics, governance codes or interplay between formal rules and common values and norms, there was no correlation with types of innovation network (see Table 5). For this reason, only formal rules and common values and norms were subject to further analysis (except *interpl*).

Particular types of innovation networks, such as inter-municipal innovation networks, may support interplay between formal and informal institutions, according to Aars and Fimreite (2005). For this reason, the authors selected a test of difference significance, which allowed them to verify the null hypothesis:

H0. *INA* = *INB* (there is equality of distribution functions of the interplay between formal and informal institutions in the compared population) against the alternative hypothesis:

H1. *INA* ≠ *INB* (there is no equality of distribution functions of the interplay between formal and informal institutions in the compared population)

where *INA* – dependent variable in the population of LGs who participate in inter-municipal innovation networks; *INB* – dependent variable in the population of LGs who participate in networks other than inter-municipal innovation networks.

Because of this, the second hypothesis was not validated (see Table 6). There is no reason to reject the null hypothesis because there is equality of distribution functions of the interplay between formal and informal institutions in the compared population. It means that the particular type of innovation network, such as inter-municipal innovation networks, does not matter in terms of the interplay between formal and informal institutions of innovation networks (*interpl*). Other types of innovation networks such as clusters, municipality forums, innovation networks or public-private partnerships are also based on the interplay between these institutions. However, only 16.3% of all innovation networks studied in practice were based on the interplay between formal rules and common values (see Table 4).

Table 5. Spearman's *rho* correlation – H2 (source: authors' compilation)

typesin	*formaru*	*sanncio*	*comvano*	*monisys*	*governor*	*comcult*	*codethi*	*interpl*
Correlation Coefficient	**0.335***	–0.005	**0.284***	0.038	–0.063	0.225	–0.173	0.082
Sig. (2-tailed)	0.019	0.970	0.048	0.797	0.666	0.120	0.234	0.577
N	49	49	49	49	49	49	49	49

Note: *. Correlation is significant at the 0.05 level (2-tailed).

Table 6. Kruskal Wallis test – H2 (source: authors' compilation)

Test Statistics			
	formaru	*comvano*	*Interpl*
Kruskal-Wallis H	3.671	0.114	0.327
df	1	1	1
Asymp. Sig.	0.055	0.736	0.567
Grouping Variable: *typesin*			

Based on theoretical research on the role of networks in the innovation process, Powell and Grodal (2005) argue that innovation networks may be based on formal institutions such as strategic alliances or research consortiums, as well as on informal ones such as trade associations or the technological community, which is in line with our results. However, in contrast to our results, they highlight that innovation networks may be based on formal or informal institutions and overlooked innovation networks based on their interplay.

Based on tracing the prosperity of nations in the 19th and 20th centuries, Phelps (2013) underlined only the importance of informal institutions such as culture or creativity to stimulate the innovation process and performance. Similarly, Sandberg et al. (2015) argue that informal institutions such as trust between members are essential to the innovation process and the success of innovation networks. Our results, by contrast, confirm that common values and norms are as important as formal rules.

Mohannak (2007) based on research into Australian high technology SMEs and in line with our results, underlined that innovation networks based only on rules or relations are rare in practice, while most innovation networks are based on formal institutions as well as on informal ones.

3.3. Importance of formal institutions for limiting institutional pathologies

Innovation networks are not always successful per se (Hotz-Hart, 2000), and institutional pathologies inside a network may lead to its collapse. Similarly, Avelino et al. (2020) argue that unfavourable institutional contexts inside or outside an innovation network or internal or external hierarchies and inequalities between members hamper the innovation process.

Polish LGs (see Table 7), which participated in our study and are members of innovation networks, indicated that their innovation networks mainly were affected by the following institutional pathologies:

i) Individual members' interests taking precedence over the common interest (*indimem*);
ii) Opportunism, distrust or rent-seeking behaviour by members (*oppodis*) or a lack of stability of members, structure and relations (*stabili*). Our study confirms that institutional pathology-free innovation networks were rare. The rarest institutional pathology was a lack of compliance with established rules (*complia*).

Not surprisingly, there were statistically significant relations between innovation networks based on formal rules and compliance with established rules, common interest, stability or lack of opportunism, distrust, and rent-seeking behaviour at the 0.01 level (2-tailed) (see Table 8). Similarly, there was a statistically significant correlation between innovation networks based on common culture or common values and norms and compliance with established rules, stability, and lack of opportunism, distrust or rent-seeking behaviour at the 0.01 level (2-tailed) and at the 0.05 level (2-tailed). There was no correlation between sanctions, governance codes, monitoring systems or codes of ethics and common interest, stability or lack of opportunism, distrust, and rent-seeking behaviour. For this reason, only formal rules, common values and norms, and common culture were subject to further analysis.

Table 7. Descriptive statistics – H3 (source: authors' compilation)

	N	Min	Max	Mean	Std. Deviation	Skewness		Kurtosis	
						Stat.	Std. Error	Stat.	Std. Error
complia	49	0.00	7.00	4.0204	2.83203	–0.555	0.340	–1.458	0.668
indimem	49	0.00	7.00	3.3061	2.45971	–0.221	0.340	–1.314	0.668
stabili	49	0.00	7.00	3.6327	2.60363	–0.420	0.340	–1.435	0.668
oppodis	49	0.00	7.00	3.4286	2.52488	–0.370	0.340	–1.411	0.668

Table 8. Spearman's *rho* correlation – H3 (source: authors' compilation)

Spearman's *rho*		*complia*	*indimem*	*stabili*	*Oppodis*
formaru	Correlation Coefficient	**0.555****	**0.488****	**0.667****	**0.594****
	Sig. (2-tailed)	0.000	0.000	0.000	0.000
	N	49	49	49	49
sanncio	Correlation Coefficient	0.246	0.162	0.243	0.138
	Sig. (2-tailed)	0.088	0.265	0.092	0.344
	N	49	49	49	49
comvano	Correlation Coefficient	**0.298***	0.243	**0.394****	**0.304***
	Sig. (2-tailed)	0.037	0.092	0.005	0.034
	N	49	49	49	49
monisys	Correlation Coefficient	**0.292***	0.169	0.194	0.150
	Sig. (2-tailed)	0.042	0.247	0.181	0.304
	N	49	49	49	49
goverco	Correlation Coefficient	0.089	0.121	0.157	0.184
	Sig. (2-tailed)	0.543	0.409	0.281	0.207
	N	49	49	49	49
comcult	Correlation Coefficient	**0.339***	0.226	**0.386****	**0.364***
	Sig. (2-tailed)	0.017	0.119	0.006	0.010
	N	49	49	49	49
codethi	Correlation Coefficient	**0.292***	0.135	0.060	–0.037
	Sig. (2-tailed)	0.042	0.356	0.683	0.798
	N	49	49	49	49

Note: **Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

Formal rules may be more effective in limiting institutional pathologies of innovation networks than sanctions, monitoring systems, culture or values (Hodgson, 2019). For this reason, the authors selected a test of difference significance, which allowed them to verify the null hypothesis:

H0. *INA = INB* (there is equality of distribution functions of institutional pathologies of innovation networks in the compared population) against the alternative hypothesis:

H1. *NA* ≠ *INB* (there is no equality of distribution functions of institutional pathologies of innovation networks in the compared population),

where *INA* – dependent variable in the population of LGs who participate in innovation networks based on formal rules; *INB* – dependent variable in the population of LGs who participate in innovation networks that are not based on formal rules.

Because of this, the third hypothesis was fully validated (see Table 9). The null hypothesis must be rejected because there is no equality of distribution functions in the compared population. It means that innovation networks based on formal rules limit institutional pathologies of innovation networks better than innovation networks based on sanctions, monitoring systems, culture, norms and values, codes of ethics or governance codes.

Sandberg et al. (2015) argue that informal institutions such as trust between members can limit institutional pathologies in innovation networks, i.e. misunderstandings or conflicts between members. It contrasts with our results, indicating that formal institutions such as formal rules can limit these pathologies. Similarly, Corsaro et al. (2012), based on a case study of two projects developed within Kilometro Rosso Science Park in Italy, highlight the significance of informal institutions such as various cultures for the success of innovation networks and for limiting potential institutional pathologies.

In line with our results, the Hofstede Insights (2020) shows that innovation networks based on formal rules should limit institutional pathologies of innovation networks better than innovation networks based on culture or trust because informal institutions in countries such as Poland, Romania, Bulgaria or Hungary are weak. Similarly, Lazzeretti and Capone (2016) stress the importance of institutional proximity such as the sharing of formal or informal rules and codes between potential members of innovation networks to the success of the innovation process and the limitation of potential institutional pathologies inside innovation networks.

Table 9. Kruskal Wallis test – H3 (source: authors own compilation)

Test Statistics				
	complia	*indimem*	*stabili*	*Oppodis*
Kruskal-Wallis H	14.798	11.447	21.340	16.920
df	1	1	1	1
Asymp. Sig.	0.000	0.001	0.000	0.000
Grouping Variable: formaru				
Kruskal-Wallis H	4.275	2.843	7.442	4.436
df	1	1	1	1
Asymp. Sig.	0.039	0.092	0.006	0.035
Grouping Variable: comvano				
Kruskal-Wallis H	5.510	2.449	7.154	6.359
df	1	1	1	1
Asymp. Sig.	0.019	0.118	0.007	0.012
Grouping Variable: *comcult*				

Regression analysis (see Supplement 5) was employed to analyse ordinal and binary variables as constituents. However, no variable other than indicating cooperation with special local institutions and innovation networks based on formal rules was consistently found to be statistically significant.

Conclusions and recommendations

This study examined cooperation between SLIs such as technology transfer centres, science parks or seed capital funds, etc., which influence the engagement of LGs in innovation networks. Furthermore, the study examined institutions such as formal rules of cooperation between members of innovation networks, sanctions for breaking the rules, monitoring systems for obeying the rules, common values and norms, codes of ethics, governance codes or a common culture if they were able to limit previously identified institutional pathologies such as opportunism, distrust, rent-seeking behaviour, individual interest, a lack of stability, and a lack of compliance with established rules.

Investigated problem was significant, as properly functioning innovation networks may generate incremental innovations such as eco-innovations or digital innovations, which may help to solve the contemporary challenges i.e. environment pollution, climate change or digital transformation. However, this process may be hampered by institutional pathologies.

Created conceptual model, which combines the relationship between formal and informal institutions and innovation networks is authors' contribution to filling the knowledge gap in institutional and innovation network theory and research. Original approach, presented in this study, allowed to show, that LGs which previously cooperated with SLIs are much more eager to participate in innovation networks. Moreover, innovation networks that are more formalised and based only on formal rules better limit institutional pathologies than innovation networks based only on informal rules, culture and values. Hence, the authors found that the primary goal of their paper was fulfilled, namely, to indicate which institutions limit institutional pathologies of innovation networks and which institutions support the decision of LGs to participate in innovation networks.

Polish LGs show how vital local institutions are to the innovation process at the local level and that cooperation with SLIs may change their behaviour to make it more innovative. There are obstacles to the success of innovation in the institutional pathologies of innovation networks, which may be limited by the formalisation of innovation networks by their orchestrators or managers. Successful innovation networks at the local level may enhance local economic development.

Moreover, the central government should consider taking into account that:

(a) Innovation networks are scarce among Polish LGs;
(b) Participation in innovation networks has many advantages for fostering innovation processes at the local level;
(c) Cooperation between LGs and SLIs influences the participation of LGs in innovation networks;
(d) New policy instruments should be applied to enhance LG participation in innovation networks, which should be especially interested in implementing social innovations.

The central government should consider supporting LGs in their innovative activities through, for example, dedicated funding for advisory support related to issues such as how to create proper governance codes for innovation networks. Besides, the practical implications for regulatory bodies highlight the need for an enforcement mechanism by means of which managers or orchestrators may support the formalisation of innovation networks, or the need to recommend a new, more innovative model of LG management instead of the previous bureaucratic management model.

The authors admit to certain limitations of their research. The first of these is connected with a lack of representatives of innovation network members. The authors studied only LGs, which are only one of many possible network members, and assume that other members would answer similarly to LGs. Secondly, the study is based on the truthfulness of the answers given by LGs, supported by filtering questions, indirect questions, lack of personal questions, or questions with detailed definitions. Thirdly, the small sample size of 184 LGs who participated in the study, and 49 who were members of innovation networks, means that the sample is not fully representative and thus does not allow for a complete generalisation of research results for the entire population. Fourth, the authors did not investigate all institutions that may influence LG participation in innovation networks, but only focused on special local institutions and formal and informal ones. There are also other institutions such as political institutions, i.e. central government, or economic institutions such as regional accounting chambers, which may impact aforementioned participation.

Future research is required to find out if the local context of LGs, i.e. economic, social, demographical, spatial or managerial indicators, may influence the engagement of LGs in innovation networks. Moreover, in-depth interviews with LGs could also shed more light on institutional pathologies within innovation networks, why particular LGs decided to participate in innovation networks or not, and how important institutional indicators are compared to economic or managerial ones.

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Author contributions

MG was responsible for concept development, study design, data collection, data analysis and interpretation, and preparing a draft version of the article. PB and SM were responsible for the critical revision of the article in terms of important intellectual content.

Disclosure statement

The authors do not have any competing financial, professional, or personal interests from other parties.

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